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ABSTRACT

For three reasons it is important to pay attention to the aspect of technology in the physics curriculum. First, physics and technology are closely related. Second, elements of technology in the physics curriculum can contribute to the process of career choice by pupils at general secondary schools when they think of going to a technical school later on. Third, starting from the physics curriculum, contributions can be made to the new, separate subject of technology. Two projects in the Education of Physics section of the Physics Faculty of the Eindhoven University of Technology address the relationship between physics and technology. The project Physics and Technology is considering elements of technology in the physics curriculum. Present activities concentrate on (1) what is technology and what is meant by technology in the physics curriculum, (2) what is the attitude of pupils and physics teachers toward technology, and (3) construction and evaluation of courses on physics and technology. The MENT (Meisjes en Natuurkunde en Techniek--Girls and Science and Technology) project is contributing to the position of girls in physics and technology education. The Education of Physics section has two tasks: physics teacher training and research in the field of physics education. (YLB)

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PHYSICS AS PREPARATION FOR TECHNICAL AND VOCATIONAL EDUCATION

Research in the Netherlands

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Text of the contribution to the programme of the International Vocational Educational and Training Association (IVETA) at the American Vocational Association at Atlanta, Georgia, USA, December 6 - 10, 1985.

Abstract

For three reasons it is important to pay attention to the aspect technology in the physics curriculum:

- physics and technology are closely related;
- elements of technology in the physics curriculum can contribute to the process of choosing of pupils at schools for general secondary education when they think of going to a technical school later on;
- starting from the physics curriculum we can contribute to the new, separate subject technology.

In our section Education of Physics of the Physics Faculty of the Eindhoven University of Technology, we pay attention to the relationship between Physics and Technology (P&T) in two projects: the project P&T and the MENT-project. Here we will mainly be concerned with the project P&T.

The aim of the project P&T is to pay attention to elements of technology in the physics curriculum. The present activities concentrate on these three questions:

- what is technology; what are we talking about when we are talking about technology in the physics curriculum;
- what is the attitude of pupils and of teachers (of physics) towards technology;
- the construction and evaluation of courses 'physics and technology'.

The aim of the MENT-project is to contribute to the position of girls in the education of physics and technology.

The section Education of Physics has two tasks: (physics) teacher training, and doing research in the field of the Education of Physics. In the education of physics we are concerned with: What to teach -in physics-, how to teach -this physics-, and how pupils and students learn -physics-.

Attention must be paid to the development of the education-of-technology. Because of the development of the education of physics one can contribute to the education-of-technology. Technology and technical education are important in our society.

The promoting of good technical education is desirable and essential. This will take time and effort.

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1. Introduction: The aspect technology in the physics curriculum

Physics and technology are closely related. Developments in physics still contribute considerably to developments in technology (e.g. transport, communication, information theory). But on the other hand there are certain technological developments that determine a progress in physical research (e.g. production of energy by means of nuclear fusion). This close relationship between physics and technology has to be visible in the physics curriculum. This is the **first reason**, for which it is important that the physics curriculum contains elements of technology.

There is, however, a **second reason**. This becomes evident when we look at physics as an inseparable part of a school for general education, which precedes a school for technical vocational education.

For a moment we will concentrate our thoughts on schools for general education for pupils aged about 12 to 18 and in that case we speak of general secondary education. For the sake of convenience we will split this up into two parts and then we will shortly and in general terms speak about a junior (general) high school for pupils aged about 12 to 15, and a senior (general) high school for pupils aged about 15 to 18. I will do this, because then people from many national systems of education will know, at least broadly what I am talking about.

In the Netherlands, as in many other countries, there are various schools for technical vocational education (in short: technical education). I will mention here the middle technical schools, the higher technical schools and the universities of technology. The middle technical schools are for pupils aged (about) 16 to 20. These schools will be attended after junior (general) high school. After senior (general) high school one can either go to the higher technical schools or to the universities of technology. Both are intended for students aged (about) 18 to 22/23.

If one wants to go to a technical school it is necessary that at junior and/or senior high school one has taken physics as a subject for examination. This is an essential requirement for admission.

Now, in general, students are going through an important process of choosing at junior and senior high school. What profession do I want to practise later on and what profession can I practise? What vocational school will I attend after high school?

I think it is important that subjects that suit this purpose, contain elements which contribute to this process of choosing a profession. Physics is such a subject. The physics curriculum must contain elements of technology, because physics and technology are directly related as being scientific and technological activities. But the physics curriculum must also contain elements of technology because this way it gives an important contribution to the choosing process of pupils in case they are considering to go to a technical vocational school.

The physics curriculum, as many other things, is subject to certain fashion-phenomena, to trends. Thus one can observe that in the last two decades the element technology in the physics curriculum in many countries has fallen into the background. What caused this is: 1. a certain larger 'humanistic' interest in general as opposed to a certain smaller 'technical-economic' interest, and 2. the fact that new and modern parts are taken up into the physics curriculum, at the expense of other parts, viz. the technological aspect of physics.

The social interest in technology and economy has strongly increased during the last 5 years (approximately). This is reflected in a growing interest in technology in the physics curriculum. Technology plays such an important part in the functioning of society, that well over 50% of the professions are of a technical kind. Young people have to take note of 'technology' at school. This is important from the point of view of general education, but also in view of the fact that they may wish to attend a technical school later on and in view of their preparation for a technical profession.

We think that it is important to pay attention to the aspect technology in the physics curriculum in scope of the preparation for a technical training.

There is a **third reason** to pay attention to technology in the physics curriculum. In the Netherlands, as in many other countries, technology has not yet acquired a place as a separate subject in the curriculum of secondary schools. (There is a subject called 'craft', but there is a lot of criticism on its function.) A separate subject technology is bound to come.

In our section Education of Physics of the Physics Faculty of the Eindhoven University of Technology we pay attention to the relationship between physics and technology in two projects:

- the project Physics and Technology, and
- the MENT-project (MENT= girls and science and technology).

In the following part we will concentrate on the project Physics and Technology.

2. The project Physics and Technology

The aim of the project Physics and Technology (the project P&T) is to pay attention to elements of technology in the physics curriculum (especially in the physics curriculum of general secondary schools, of junior general high schools).

Questions we asked ourselves are: what aspects of technology are taken up into the present physics curriculum; what is meant by 'technology'; can we give examples of physics courses, in which more and/or better technology can be found?

The project P&T is one of the activities of the Department of Physics Education of the Faculty of Technical Physics of the Eindhoven University of Technology. In the first instance it has been set up as a four-year project. At the moment 2 people are working on the project, one of whom is the project leader Drs. Marc de Vries, and I assistant, while I, being the chairman of the Department of Educational Physics, am responsible for the progress and the quality of the project.

The project P&T is a development and research project: we develop material that can be used in schools, we also give a scientific contribution to the education of physics and technology. Moreover, the project has been structured in such a way, that both physics teachers and technology teachers, and students can take part in it.

The activities of the project are now moving along three lines:

1. What is technology; what are we talking about when we are talking about technology in the physics curriculum;
2. what is the attitude of pupils and of teachers (of physics) towards technology;
3. the construction and evaluation of courses 'physics and technology'.

2.1 What is technology?

What is technology? What technology are we talking about? What are the fundamental characteristics of technology that we want to integrate in the physics curriculum?

Therefore one of the lines of the project is looking for a well-founded answer to the question 'What is technology?'. What is the concept of technology in the courses we want to construct and evaluate?

We have executed a literature study into the question what the characteristics of technology are. Then a recapitulating report has been written and sent to a number of experts (technology-philosophers, teachers at technical schools and several others) with a request to comment on it.

On the basis of the comment, which is being collected now, the report will be rewritten. We expect that an English version will be ready in spring or early summer 1986.

I will summarise the (tentative) results here very briefly:

1. technology is a specifically human activity,
2. the three pillars of technology are: matter, energy and information,
3. technology is closely related to the natural sciences,
4. designing and problem solving play a major part in technology,
5. technology severely intervenes all aspects of society: economy, social relations, labour.

In the case of education this means:

1. pupils must learn to give a value judgement to technology from their own view of life.

They must learn to see that technology is not an area specifically for men, but that women can also work in it.

In education attention must be paid to the historical aspect of technology.

The remarks above are linked up with the fact that not the machine but the human being is at the centre of technology;

2. technology has to be presented in all its diversity.

This concerns diversity both with reference to the keystones of technology (matter, energy and information) and with reference to the subsidiary fields of technology and the zones in which one gets into contact with technology;

3. the relationship between physics and technology has to be pointed out to the pupils. This concerns the mutual influence both of knowledge and of methodology;
4. sufficient attention must be paid to designing and problem solving, just as to acting in a practical-technical way. Pupils must make something themselves;
5. pupils must be urged to think about the position of technology in society and its influence upon the way society is organised. Their own responsibility in associating with technology and the students being a consumer themselves is also part of this.

When the pupils' environment is taken as a starting-point for the content of a subject technology, this might implicate the choice of a thematic structure.

I refer to the summary of the report 'What is technology?' (see Appendix 1).

2.2 What is the concept of and the attitude towards technology?

Attention for technology in education will have to contribute to a formation or an improvement of the idea pupils have of technology. However, little is known of the idea pupils have of technology. To be able to give founded recommendations, at least something will have to become known of this idea. It is important to know whether pupils have a clear idea of technology and where this idea may be distorted. Only when this is clear, can the project P&T develop courses in a meaningful way, which may contribute to the formation of pupils' ideas. Then too it can be judged to what extent the other (subsidiary-) curricula, of which an inventory will be made, contribute to the filling of gaps, and/or the removal of distortions in the idea pupils have of technology.

So there is clearly a relationship between the attitude-measure and the other parts of the project P&T. The attitude-measure is an important part of the whole project.

We made the decision to measure first of all the attitude of pupils aged (about) 13 of junior (general) high schools, in the Netherlands this is the second year of general secondary schools. We made this decision because immediately after this year pupils have to make a first choice whether they want to take physics, and also mathematics, as an exam subject. If they do not take these subjects as exam subjects this means that the entry to a technical school will be blocked for them.

As for technology, the curriculum does not prepare pupils well for making these important choices. One can wonder if pupils at that age have enough knowledge to make decisions that can have such important consequences. What do 13-year-old pupils know about technology? What is their interest in it? From experiences in the MENT-project (in Dutch: Meisjes en Natuurkunde en Techniek), concerning the relation 'girls and technology' we expect 13-year-old girls to have less an idea of what technology is than boys have and a less positive attitude towards technology.

To test these hypotheses we do an investigation into the conception of and the attitude towards technology of 13-year-old students.

As a first step we interviewed 12 students, asking them questions such as: what do you think technology is, how important is technology to you?

Secondly, we asked 48 pupils of two different schools to write down their ideas about technology, answering 10 open-ended questions we presented to them.

The answers we got in both steps were used to construct a questionnaire consisting of 80 questions to be answered in a 5-point Likert-scale. The questions could be divided into 8 sections: general knowledge of technology, interest, importance, etcetera.

To avoid misunderstanding: the questions in the questionnaire were not grouped in these sections; they were offered in a mixed order.

The questionnaire was presented to some 3,000 13-year-old pupils of different schools in different parts of the country.

The results were factor-analysed. 20 factors were found, 14 of which could be identified. Factor scores were computed and the differences between girls and boys were tested for significance.

Conclusions are that it is difficult for pupils to indicate what technology is. They are aware of the importance and the diversity of technology.

Girls are less interested in technology than boys are.

Girls as well as boys think that girls are apt for technology.

To have first possibilities to compare the results with other countries a translation of the same questionnaire was presented to Polish pupils of the same age. There is correspondence and arrangements are made with investigators in Australia, Canada, Hungary, Nigeria, Poland, USA and the UK to do the same.

First results of a pilot study will be discussed in a workshop at the Eindhoven University of Technology, the Netherlands, March 1986.

A report of the workshop will be available in summer 1986.

2.3 The construction and evaluation of courses Physics and Technology

The question is what elements of technology can be introduced in the teaching of the subject physics to improve the idea that pupils have of technology. The answering of this question takes place on the basis of the evaluation of a number of example series of lessons of physics, with material that is to be developed in this project, in which the actual character both of physics and of technology and the relationship between these two plays an important part. In a later stage of the project more attention will be given to the concept **evaluation** for the purpose of this project.

The courses are written by teachers at general secondary and pre-university schools, supervised by someone who cooperates in the project.

The subjects of the **courses** that have been developed are:

Electrical equipment at home,
Water at home,
Communication,
Making musical instruments.

An English version both of the courses and of the teachers' guides belonging to each of the courses is available.

For the contents of the courses I refer to Appendix 2.

Courses, yet to be developed, are:

Do-it-yourself,
Lighting,
Transport,
Medical Technology.

3. The MENT-project. Special attention for the education of physics and technology for girls.

In the Netherlands the number of girls that take part in technical vocational education is much smaller than the number of boys. Dependent on the kind of technical school the number of female students varies between 1 and 5% of the total population! However, we can observe that this number is growing every year, even though it is slowly. At general schools we see that in all places where a choice is possible girls choose physics as an exam subject far less often than boys. Here the figures vary between a choice of 10 to 25% on the part of the girls and of 25 to 60% on the part of the boys. The consequence of not taking physics as an exam subject (a choice which is often made already at the age of 13) is, that later on it is impossible to go to a technical school.

Apart from the project P&T there is another project executed in the Department of the Education of Physics, the so-called MENT-project (MENT is, in Dutch: meisjes, natuurkunde en techniek; in English: girls and physics and technology).

The aim of the MENT-project is to contribute to the position of girls in the education of physics and technology.

There is also international interest in the position of girls and women in physics, in science in general and in technology, because the phenomenon that we are concerned with here, can be found in many -mainly western- countries.

In 1981 we organised the first international GASAT-conference in Eindhoven. GASAT stands for girls and science and technology. A second conference was held in Oslo, Norway in 1983. GASAT-3 took place in London (UK) in 1985. GASAT-4 will be held in Ann Arbor, Mich., USA in 1987.

Also in the project P&T special attention is given to the position of girls in the education of physics and technology.

The fact that technology is something for all people, for women and men alike, is also part of the answer to the question 'What is technology?'. When applied to education: technical education has to be as attractive to girls as it is to boys. In the attitude-measure we are trying to find what 13-year-olds think of it: is technology mainly something for boys; can girls take a technical training just as well as boys? While making the coursebooks we see to it, that they are as appealing to girls as they are to boys.

4. The development of the education-of-technology

The project P&T has taken its place in our Section Education of Physics. This Department has two tasks: taking care of the curriculum for the teacher training of physics for those students (about 20%) of our Physics Faculty that want to become a teacher, and doing research in the field of physics education.

First of all something about the terminology. As I discovered at conferences, in a number of European languages on the continent the word 'didactics' is used (in Dutch: didactiek, and particularly 'vakdidactiek'; in German: Didaktik and also 'Fachdidaktik').

In my opinion it is best to use phrases like 'teaching methodology', 'the teaching of ...' and 'the education of ...' in English. I have the impression that the word 'didactics' is more a Germanism, a 'Dutchism' in the English language, than that it is a right and meaningful English word.

I think that in the education of physics one has to be occupied with (in any possible sequence):

- **what to teach,**
- **how to teach it, and**
- **how pupils learn.**

This means, and one has to realise this:

- what choices are made when fixing a **physics curriculum,**
- how does one **teach this physics,**
- how do pupils **learn physics.**

I am only trying to say that in the teaching methodology of physics, people are less occupied with general pedagogic and didactic questions, but more and specially with questions directly dealing with the subject physics.

People who are occupied with the **development of the education** - in this case the education of **physics** - are usually employed by a teacher training institute, and a teacher training institute at university in particular. It is easy to explain and to understand the reason of this.

The development of the education - always in general, here of physics in particular - as a specific activity is very young. The education of physics as a scientific discipline is even younger than educational sciences (as there are psychology, pedagogy, sociology, ... etc.). The development of the teaching methodology for physics means a development in an interdisciplinary situation: physics, the teaching and learning of physics and branches of the social sciences will have to cooperate.

It does not take long to come to the conclusion that this takes some time and effort. But the development of both beta sciences (physics) and social sciences (education), results in the fact that one can no longer take an amateur approach to the education of physics, as was done for a long time, and is still sometimes done.

What makes the research task within the teacher training institutes at university attractive is:

- the people there know a lot about the situation at schools. There is a direct relationship with, what we call, the field of education. They will not make research into education that is very theoretical and far away from the practical situation in the classroom;
- within the university there is a great deal of professional knowledge, both for the discipline (e.g. physics) and for education. Developments in physics can be rendered into education rather quickly.

What makes the structure unattractive is:

- teacher training institutes are not special research institutes,
- research may be split up, when research at various faculties is insufficiently coordinated. Apart from this it is important to have some sort of national coordination.

Research into education in general is a young branch of science. The development takes time. This is no doubt also valid for research into education at the teacher training institutes at university, which is often very tightly linked to the subject (e.g. physics).

An important property of the research is, that students can take part in it. Moreover, it will have to be organised in such a way, that teachers can also take part in it.

In the foregoing I wanted to make clear what we are trying to achieve in our project P&T and also how we are pursuing this object.

I think it is justified to remark that the developing and evaluating of technical vocational education deserves more attention. One of the causes for this backlog might be the fact that vocational education is often especially something for your neighbour's children. In physics and mathematics one is a step further as far as the development and evaluation of the education is concerned.

If one has a look at the development of the teaching methodology of physics and that of related subjects, it can be observed that the education of physics develops relatively well. The same applies to mathematics and biology. I think it is possible to remark that the developments for foreign languages and social subjects like geography and history, as far as teaching methodology is concerned, are smaller. Here I will not try to explain this.

What is really striking is a retardation of what I would like to call the education of technology. I think I can mention two explanatory factors for this:

- technology with the extent, the social influence and impact as we know it, exists only a few decades. A development in education takes more time;
- education of technology hardly has a place in general education. And particularly at universities there was and is relatively little attention for this branch of education. An actual involvement would require a kind of agreement between technological science and issues of a social nature.

This agreement evokes a certain tension. Its development will take time.

In education a close relationship between physics and technology, or more generally, technological education, is observed. Involvement in the development of the teaching methodology of physics frequently points to an absence of the development of the teaching methodology of technology. The development of the education of physics can and will have to give a major contribution to the development of the education of technology.

5. International cooperation

Technology is an important element in our society. This is not yet sufficiently reflected in education. A general education, for a better understanding of the way the present society is functioning, requires knowledge of, skills in and a certain attitude towards technology. Because over 50% of the professions is of a technical kind, technical vocational education, and the preparation for it, is extremely important.

The promoting of good technical education is desirable and essential. This will take time and effort. Therefore international cooperation is highly important. That is why we provide English translations of part of the products of the project P&T.

I hope that my lecture has been able to contribute to the promotion of this international cooperation.

Appendix I

Summary of the report 'What is technology?'

In the project Physics and Technology courses of physics have been developed, in which technology plays a major part.

It is important to make clear what the concept technology means before shape is given to technology in education.

In this report on the basis of an extensive literature study a survey is given of the most important characteristics of technology and the lines are extended to education.

The report is meant to be an account of the contents of the courses P&T.

In chapter 1 the origin of the words technics and technology is mentioned. According to authors that were studied these terms are interchangeable.

Chapter 2 gives the five general characteristics of technology, which are continually found in most authors.

1. Technology is a specifically human activity.

This implicates, that in the view of technology the view of humanity determines the way technology is regarded.

It also implicates, that technology is both a men/boys activity and a women/girls activity.

Finally it implicates, that technology has developed the way man himself has developed.

2. The three pillars of technology are: matter, energy and information. In the course of history the accent has been shifted from the first, via the second to the third pillar. Yet all three of them still play a part in modern technology.

3. Technology is closely related to the natural sciences.

Originally technology was independent of natural sciences, but in the course of time an interaction and a mutual influence came into being between the two of them.

4. Designing and problem solving play an important part in technology. Frequently skills in this field, as well as practical-technological skills, are appealed to.

Knowledge of characteristics of materials and tools is essential.

5. Technology severely intervenes all aspects of society: economy, social relations, labour.

A separate discipline (technology assessment) is occupied with the possible consequences of technological applications.

Chapter 3 deals with the consequences of the considerations for the content of technology in education that are presented in chapter 2.

Now the same characteristics are discussed once more, this time concentrating on education.

In chapter 4 it is investigated how these considerations are put into practice in the courses that have been developed in the project Physics and Technology.

The aim of these courses is to contribute to the insight into physics and technology and into the relationship between them.

The courses explicitly pay attention to the designing process.

In the theme **Making musical instruments** the pupils will design a simple flute. The guitar and the electronic musical instruments are also dealt with in this course.

The theme **Electrical equipment at home** has pupils designing a simple hotplate and furthermore this course deals with the coffee machine and the iron.

In the theme **Communication** pupils will design a circuit to transmit a message in Morse-code. Afterwards they will examine the way the telephone operates and they will get better acquainted with the optical fibre technology.

The theme **Water at home** deals with the way water becomes available at home by means of water towers and pumps. The pupils will compare gas heater and boiler and see the way the tap, the cistern of the toilet and the stench-trap operate.

Themes that are still to be developed are: Lighting, Medical Technology, Do-it-yourself, Transport and Energy and industry.

Evaluation after use in the classroom will have to show to what extent the set aims are attained.

Appendix 2

Tables of contents of written themes of the project Physics & Technology

Electrical equipment at home

1. Concepts of physics, electricity
2. Designing a piece of electrical equipment
3. The coffee machine
4. The iron
5. Usage of electrical equipment at home

Revision Sheets

1. Concepts of physics
2. Designing a piece of electrical equipment
3. Coffee machine and iron

Additional Material

1. History of electrical equipment
2. Appliances with electro-magnets
3. Repairing electric equipment

Communication

1. Concepts of physics: electricity and light
2. How to convey a message over a great distance
3. The telephone
4. The optical fibre
5. Communication in our world

Revision Sheets

1. History of tele-communication: from semaphore to satellite
2. Making a model of an optical fibre
3. Experiments with phones

Additional Material

1. Concepts of physics
2. Designing tele-communication equipment
3. Telephone and optical fibre

Water at home

1. Concepts in physics: fluid pressure and heat transport
2. How water is supplied at home
3. The gas heater and the boiler
4. Taps and the WC
5. Using water economically

Revision Sheets

1. Concepts of physics
2. Making clean drinking water
3. Central Heating

Additional Material

1. History of water-supply
2. Making clean drinking water
3. Central heating

Making musical instruments

1. Concepts of physics: sound
2. Designing and making a flute
3. The guitar
4. Electrical instruments
5. Music in your life

Revision Sheets

1. Concepts of physics
2. Designing and making musical instruments
3. Guitar and electrical musical instruments

Additional Material

1. History of electrical instrument
2. Building an electrical guitar
3. The trumpet